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STATEMENT

I, Futoshi Suzuki, a citizen of Japan, residing at 3D, Kopo-Shimizu, 1839 Noritake, Gifu-shi, Gifu-ken, Japan, hereby state that I am the translator of the attached document and I believe it is an accurate translation of the Japanese Patent Application No. 2001-053401, filed on February 28, 2001.

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Translator
Dated this 14th date of October, 2003

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This is to certify that the annexed is a true copy of the following application as filed with this Office.

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Applicant(s): NIPPON SHEET GLASS CO., LTD.

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[Title of Document] SPECIFICATION

[Title of the Invention] Scanning Method and Apparatus, Light Intensity Testing Method and Apparatus, and Aligning Method and Apparatus

[Scope of the Invention]

[Claim 1] A scanning method for causing light directing means located at a position intersecting an optical axis of incident light to scan in two directions on the optical axis, the method being characterized by:

performing scanning in one of the two directions faster than scanning in the other direction.

[Claim 2] The scanning method according to claim 1, characterized in that the faster scanning is performed in a range of 100 Hz to 1 kHz, and the slower scanning is performed in a range of 0.1 to 10 Hz.

[Claim 3] The scanning method according to claim 1, characterized in that the faster scanning is performed in a range of 200 to 600 Hz, and the slower scanning is performed in a range of 0.2 to 5 Hz.

[Claim 4] The scanning method according to claim 1, characterized in that the faster scanning is performed in a range of 300 to 500 Hz, and the slower scanning is performed in a range of 0.5 to 2 Hz.

[Claim 5] A light intensity testing method for detecting the intensity of light that impinges on light directing means located at a position intersecting an optical axis of incident light while causing the light directing means to scan in two directions on the optical axis, the method being characterized by:

performing scanning in one of the two directions faster than scanning in the other direction.

[Claim 6] A light intensity testing method for detecting the intensity of light that impinges on light directing means while causing at least one of the light directing means and a testing work located at a position intersecting an optical

axis of incident light to scan in two directions on the optical axis, the method being characterized by:

performing scanning in one of the two directions faster than scanning in the other direction.

[Claim 7] The light intensity testing method according to claim 5 or 6, characterized by storing a position of the light directing means at which a light intensity reaches a maximum.

[Claim 8] The light intensity testing method according to any one of claims 5 to 7, characterized in that scanning in the two directions refers to at least either of two directions in angle or two directions in position.

[Claim 9] An aligning method for aligning an alignment work located on an optical axis of incident light while causing light directing means located at a position intersecting the optical axis of the incident light in two directions and detecting the intensity of light that impinges on the light directing means, the method being characterized by:

performing scanning in one of the two directions faster than scanning in the other direction.

[Claim 10] An aligning method for aligning an alignment work, wherein light directing means and an alignment work are located at a position intersecting an optical axis of incident light, and wherein the intensity of light that impinges on the light directing means is detected while causing at least one of the light directing means and the alignment work to scan in two directions on the optical axis, the method being characterized by:

performing scanning in one of the two directions faster than scanning in the other direction.

[Claim 11] The aligning method according to claim 9 or 10, characterized by storing a position of the light directing means at which a light intensity reaches a maximum.

[Claim 12] The aligning method according to any one of claims 9 to 11, characterized by storing a position of the

light directing means at which a light intensity reaches a maximum, and adjusting the alignment work along the optical axis by moving the alignment work forward or backward.

[Claim 13] The aligning method according to claim 12, characterized in that the alignment work has a tube, a collimation lens and a capillary inserted in the tube, and an optical fiber inserted in or secured to the capillary, wherein the optical fiber is moved forward or backward.

[Claim 14] A scanner characterized by:

light directing means located at a position intersecting an optical axis of incident light;

scanning means for causing the light directing means to scan in two directions on the optical axis; and

controlling means for controlling operation of the scanning means such that scanning in one of the two directions is performed faster than scanning in the other direction.

[Claim 15] A light intensity testing apparatus characterized by:

light directing means located at a position intersecting an optical axis of incident light;

scanning means for causing the light directing means to scan in two directions on the optical axis;

light intensity detecting means for detecting the intensity of light that impinges on the light directing means; and

controlling means for controlling operation of the scanning means such that scanning in one of the two directions is performed faster than scanning in the other direction.

[Claim 16] A light intensity testing apparatus characterized by:

light directing means located at a position intersecting an optical axis of incident light;

work holding means for holding a testing work on the

optical axis in a position towards a light incoming side with respect to the light directing means;

scanning means for causing at least one of the light directing means and the work holding means to be scanned in two directions;

light intensity detecting means for detecting the intensity of light that impinges on the light directing means; and

controlling means for controlling operation of the scanning means such that scanning in one of the two directions is performed faster than scanning in the other direction.

[Claim 17] The light intensity testing apparatus according to claim 16, characterized in that the scanning means is at least one of scanning means that causes the light directing means to scan on the optical axis and scanning means located on the work holding means to scan the testing work on the optical axis.

[Claim 18] The light intensity testing apparatus according to any one of claims 15 to 17, characterized by a storing means for storing a position of the light directing means at which the light intensity reaches a maximum based on a detected output from the light intensity detecting means.

[Claim 19] The light intensity testing apparatus according to any one of claims 15 to 18, characterized in that the light directing means is a mirror, wherein reflected light from the mirror impinges on the light intensity detecting means.

[Claim 20] The light intensity testing apparatus according to any one of claims 15 to 18, characterized in that the light directing means is a lens, wherein light that is transmitted through the lens impinges on the light intensity detecting means.

[Claim 21] An aligning apparatus characterized by the light intensity testing apparatus according to any one of claims 15

to 20, wherein the testing work is an alignment work.

[Claim 22] The aligning apparatus according to claim 21, characterized by adjusting means for adjusting the position of the aligning work along the optical axis by moving the alignment work forward or backward.

[Claim 23] The aligning apparatus according to claim 22 characterized by storing means for storing the position of the aligning work moved by the adjusting means.

[Detailed Description of the Invention]

[0001]

[Industrial Field of Application]

The present invention relates to a light intensity testing method and an apparatus, and an aligning method and an apparatus.

[0002]

[Prior Art]

Fig. 13 is a schematic diagram illustrating a conventional fiber collimator aligner. The fiber collimator aligner is formed as described below.

[0003]

That is, light emitted from a light source 51 reaches a mirror 14 through a first branch optical fiber 52 and an optical splitter 53 from a collimation lens 34.

The light 59 reflected by the mirror 14 is converged by the collimation lens 34 and impinges on a light intensity measuring device 75 through an optical fiber 36, an optical splitter 53 and a second branch optical fiber 54. In this case, the light intensity of the reflected light that passes through an alignment collimator 32 is changed in accordance with the angle of the mirror 14.

[0003]

A conventional aligning method independently swings the mirror 14 in the vertical direction (θx) and in the horizontal direction (θy). That is, in the conventional aligning method, the angle of the mirror 14 is separately

changed in the vertical direction and in the horizontal direction. Accordingly, the light intensity of the reflected light that enters the alignment collimator 32 is changed in accordance with the angle of the mirror 14, and the light intensity can be measured from an output value of the light intensity measuring device 75. The angle of the mirror 14 is changed until the light intensity of the reflected light reaches the maximum. After adjusting the angle of the mirror 14, the position of the optical fiber 36 in the Z-axis direction is changed to vary the angle of the mirror 14 again such that the light intensity reaches the maximum. At this position, the optical fiber 36 is fixed to a capillary 35 with an adhesive, which is not shown.

[0005]

[Problems that the Invention is to Solve]

In the foregoing manner, the conventional aligning method swing the mirror 14 in the vertical direction and in the horizontal direction separately with reference to the output value of the light intensity measuring device 75 such that the light intensity reaches the maximum. Further, the position of the optical fiber 36 in the Z-axis direction is changed such that the light intensity reaches the maximum again. Therefore, the aligning operation involves a trial and error process and takes a long time.

[0006]

It is an objective of the present invention to provide a light intensity testing method and an apparatus which reduce a time required for detecting an optimized position at which a light intensity reaches the maximum, and an aligning method and an apparatus.

[0007]

[Means for Solving the Problems]

To achieve the above objective, the invention as set forth in claim 1 provides a scanning method for causing light directing means located at a position intersecting an optical

axis of incident light to scan in two directions on the optical axis. The method is characterized by performing scanning in one of the two directions faster than scanning in the other direction.

[0008]

The invention as set forth in claim 2 provides the scanning method according to claim 1, characterized in that the fast scanning is performed in a range of 100 Hz to 1 kHz, and the slow scanning is performed in a range of 0.1 to 10 Hz.

The invention as set forth in claim 3 provides the scanning method according to claim 1, characterized in that the fast scanning is performed in a range of 200 to 600 Hz, and the slow scanning is performed in a range of 0.2 to 5 Hz.

[0009]

The invention as set forth in claim 4 provides the scanning method according to claim 1, characterized in that the fast scanning is performed in a range of 300 to 500 Hz, and in the slow scanning is performed in a range of 0.5 to 2 Hz.

The invention as set forth in claim 5 provides a light intensity testing method for detecting the intensity of light that impinges on light directing means located at a position intersecting an optical axis of incident light while causing the light directing means to scan in two directions on the optical axis. The method is characterized by performing scanning in one of the two directions faster than scanning in the other direction.

[0010]

The invention as set forth in claim 6 provides a light intensity testing method for detecting the intensity of light that impinges on light directing means while causing at least one of the light directing means and a testing work located at a position intersecting an optical axis of incident light to scan in two directions on the optical axis. The method is characterized by performing scanning in one of the two

directions faster than scanning in the other direction.

[0011]

The invention as set forth in claim 7 provides the light intensity testing method according to claim 5 or 6, characterized by storing a position of the light directing means at which a light intensity reaches a maximum.

The invention as set forth in claim 8 provides the light intensity testing method according to any one of claims 5 to 7, characterized in that scanning in the two directions refers to at least either of two directions in angle or two directions in position.

[0012]

The invention as set forth in claim 9 provides an aligning method for aligning an alignment work located on an optical axis of incident light while causing light directing means located at a position intersecting the optical axis of the incident light in two directions and detecting the intensity of light that impinges on the light directing means. The method is characterized by performing scanning in one of the two directions faster than scanning in the other direction.

[0013]

The invention as set forth in claim 10 provides an aligning method for aligning an alignment work. Light directing means and an alignment work are located at a position intersecting an optical axis of incident light. The intensity of light that impinges on the light directing means is detected while causing at least one of the light directing means and the alignment work to scan in two directions on the optical axis. The method is characterized by performing scanning in one of the two directions faster than scanning in the other direction.

[0014]

The invention as set forth in claim 11 provides the aligning method according to claim 9 or 10, characterized by

storing a position of the light directing means at which a light intensity reaches a maximum.

The invention as set forth in claim 12 provides the aligning method according to any one of claims 9 to 11, characterized by storing a position of the light directing means at which a light intensity reaches a maximum, and adjusting the alignment work along the optical axis by moving the alignment work forward and backward.

[0015]

The invention as set forth in claim 13 provides the aligning method according to claim 12, characterized in that the alignment work has a tube, a collimation lens and a capillary inserted in the tube, and an optical fiber inserted in or secured to the capillary. The optical fiber is moved forward or backward.

[0016]

The invention as set forth in claim 14 provides a scanner characterized by: light directing means located at a position intersecting an optical axis of incident light; scanning means for causing the light directing means to scan in two directions on the optical axis; and controlling means for controlling operation of the scanning means such that scanning in one of the two directions is performed faster than scanning in the other direction.

[0017]

The invention as set forth in claim 15 provides a light intensity testing apparatus characterized by: light directing means located at a position intersecting an optical axis of incident light; scanning means for causing the light directing means to scan in two directions on the optical axis; light intensity detecting means for detecting the intensity of light that impinges on the light directing means; and controlling means for controlling operation of the scanning means such that scanning in one of the two directions is performed faster than scanning in the other

direction.

[0018]

The invention as set forth in claim 16 provides a light intensity testing apparatus characterized by: light directing means located at a position intersecting an optical axis of incident light; work holding means for holding a testing work on the optical axis in a position towards a light incoming side with respect to the light directing means; scanning means for causing at least one of the light directing means and the work holding means to be scanned in two directions; light intensity detecting means for detecting the intensity of light that impinges on the light directing means; and controlling means for controlling operation of the scanning means such that scanning in one of the two directions is performed faster than scanning in the other direction.

[0019]

The invention as set forth in claim 17 provides the light intensity testing apparatus according to claim 16, characterized in that the scanning means is at least one of scanning means that causes the light directing means to scan on the optical axis and scanning means located on the work holding means to scan the testing work on the optical axis.

[0020]

The invention as set forth in claim 18 provides the light intensity testing apparatus according to any one of claims 15 to 17, characterized by a storing means for storing a position of the light directing means at which the light intensity reaches a maximum based on a detected output from the light intensity detecting means.

[0021]

The invention as set forth in claim 19 provide the light intensity testing apparatus according to any one of claims 15 to 18, characterized in that the light directing means is a mirror, wherein reflected light from the mirror impinges on the light intensity detecting means.

[0022]

The invention as set forth in claim 20 provide the light intensity testing apparatus according to any one of claims 15 to 18, characterized in that the light directing means is a lens, wherein light that is transmitted through the lens impinges on the light intensity detecting means.

[0023]

The invention as set forth in claim 21 provide an aligning apparatus characterized by the light intensity testing apparatus according to any one of claims 15 to 20. The testing work is an alignment work.

The invention as set forth in claim 22 provide the aligning apparatus according to claim 21, characterized by adjusting means for adjusting the position of the aligning work along the optical axis by moving the alignment work forward or backward.

[0024]

The invention as set forth in claim 23 provide the aligning apparatus according to claim 22 characterized by storing means for storing the position of the aligning work moved by the adjusting means.

According to the present invention, scanning is performed slowly in one direction while scanning fast in the other direction to scan each angular position in the associated direction little by little at a short time. Therefore, the set ranges that require measurement can be fully scanned in a short time. Thus, detection of the light intensity can be performed in a very short time during, for example, alignment.

[0025]

[Embodiment]

Embodiments of the present invention will be described with reference to drawings. In the descriptions of the embodiments, like members are given the like numbers and duplicate explanations are omitted.

[First Embodiment]

A fiber collimator aligning method and an apparatus according to a first embodiment of the present invention will be described with reference to Figs. 1 to 4.

[0026]

A fiber collimator aligner of the first embodiment is shown in Figs. 1 to 3. As illustrated in Figs. 1 to 3, the fiber collimator aligner comprises a light directing unit 50. The light directing unit 50 includes a light source 51; a first branch optical fiber 52 optically connected to the light source 51; an optical splitter 53; and a second branch optical fiber 54 optically connected to the optical splitter 53. The optical splitter 53 is optically connected to the optical fiber 36. Preferably, a blocking part such as an isolator for blocking return light to the light source 51 may be provided between the first branch optical fiber 52 and the light source 51. The aligner further includes light directing means, which is a reflector 10 in this embodiment; an aligning part 30 on which light reflected from the reflector 10 impinges, adjusting means, which is a movable part 40 in this embodiment, for moving the optical fiber 36 in a longitudinal direction; a light directing unit 50 connected to the optical fiber 36; and a signal processing part 70. The optical fiber 36 is inserted into the aligning part 30.

[0027]

The reflector 10 includes a first rotating body 11, which is reciprocally rotatable in θx direction at a low speed by a motor 15 shown in Fig. 3 in a vertical plane; a second rotating body 12 supported on the first rotating body 11 and has an output shaft 13, which is reciprocally rotatable about θy direction in a horizontal plane; and a mirror 14 fixed to the output shaft 13. In the first embodiment, the first rotating body 11 and the second rotating body 12 serve as scanning means. The first rotating

body 11 is rotated at a high speed and the second rotating body 12 is rotated at a low speed. The rotation of the first rotating body 11 in the θx direction and the rotation of the second rotating body 12 in the θy direction are rotations of scanning. The second rotating body 12 is driven by, for example, a voice coil or a piezo actuator.

[0028]

The aligning part 30 includes work holding means, which is a work holder 31 in this embodiment. The work holder 31 holds an alignment work, i.e., the alignment collimator 32. As illustrated in Fig. 2, the alignment collimator 32 includes a tube 33. When a capillary 35 is fixed inside or formed in the tube 33 in advance, the optical fiber 36 is inserted into the capillary 35. Alternatively, when the optical fiber 36 is fixed to the capillary 35, the capillary 35 guides the optical fiber 36 into the tube 33. A collimation lens 34 is located inside the sleeve 33.

[0029]

The movable part 40 includes an optical fiber moving base 41; an optical fiber positioning base 42 placed on the moving base 41; an optical fiber fixing plate 43 placed on the positioning base 42; and a Z-axis drive motor 44. The optical fiber 36 is fixed on the optical fiber positioning base 42 by the optical fiber fixing plate 43. The optical fiber positioning base 42 is moved in the longitudinal direction, i.e., the Z-axis direction of the capillary 35 by the Z-axis drive motor 44.

[0030]

Fig. 3 is a schematic diagram of the signal processing part 70, which serves as light intensity detecting means and controlling means for the fiber collimator aligner of the first embodiment. The signal processing part 70 includes a central processing unit (CPU) 71; a ROM 72 for storing data used to operate a program illustrated in Fig. 4; a storage means or a RAM 73 for temporarily storing, for example,

measured data; a cathode ray tube (CRT) display 74 for displaying results of measurements; a light intensity measuring device 75; a Z-axis driving circuit 76 for controlling the Z-axis drive motor 44; a driving circuit 77 of the motor 15 for vertically (θx) swinging the first rotating body 11 ; a driving circuit 78 of the actuator 12a for horizontally (θy) swinging the second rotating body 12; and an angle output circuit 79. An angle data of the first rotating body 11 and an angle data of the second rotating body 12 are sent to the angle output circuit 79. In the first embodiment, the CPU 71, the ROM 72, the RAM 73, the CRT 74, and the light intensity measuring device 75 serve as the light intensity detecting means. The Z-axis drive signal processing circuit 76, the driving circuit 77, the driving circuit 78, the angle output circuit 79, the CPU 71, and the ROM 72 serve as the controlling means.

[0031]

Light emitted from the light source 51 passes through the first branch optical fiber 52, the optical splitter 53 and the optical fiber 36, and is converted to parallel light 59 by the collimation lens 34.

The parallel light 59 is reflected by the mirror 14, and converged by the collimation lens 34. The converged light 59 further passes through the optical fiber 36, the optical splitter 53 and the second branch optical fiber 54, and impinges on the light intensity measuring device 75. The output of the light intensity measuring device 75 is sent to the CPU 71 in synchronism with the output of the angle output circuit 79. Accordingly, the light intensity at each predetermined angle is detected. The CPU 71 finds the angle at which the light intensity reaches a maximum.

[0032]

The mirror 14 automatically rotates in two directions (θx, θy) for scanning. Since the rotation in one of the directions is faster than the rotation in the other direction,

the signal processing part 70 can detect the maximum value of the light intensity within a scanning angle range in a short time.

[0033]

Next, the aligning method according to this embodiment will be described with reference to a flow chart of Fig. 4. In the flow chart, the program stored in the ROM 72 is executed by the control of the signal processing part 70.

[0034]

In step S1, the CPU 71 sets a θx angle range of the first rotating body 11 and a θy angle range of the second rotating body to be slightly large. Since the angle ranges are set relatively large before scanning in two directions (θx, θy), the reflected light 59 can be found even if the optical axis of the collimation lens 34 slightly deviates from the reflected light 59 of the mirror 14. Therefore, the detection of the light 59 is executed.

[0035]

In step S2, the CPU 71 calculates the center of a light intensity distribution of the captured light 59. The CPU 71 reduces the θx angle range of the first rotating body 11 and the θy angle range of the second rotating body 12 based on the calculated result. The CPU 71 executes scanning in two directions (θx, θy) with the calculated center being set as the origin. In this scanning, the speed of the scanning in the θx direction is several hundreds of times higher than the speed of the scanning in the θy direction. Therefore, scanning is performed slowly in one direction while scanning fast in the other direction to scan each angular position in the associated direction little by little at a short time. Therefore, the set ranges that require measurement can be fully scanned in a short time. The CPU 71 stores the light intensity distribution at each angle in the RAM 73.

[0036]

In step S3, the CPU 71 detects a maximum value of the

light intensity from the light intensity distribution stored in the RAM 73.

In step S4, the CPU 71 drives the Z-axis drive motor 44 to move the optical fiber positioning base 42 in the Z-axis direction by a predetermined distance. In this manner, the distance between the optical fiber 36 and the collimation lens 34 is changed by a predetermined distance.

[0037]

In step S5, the θx angle range of the first rotating body 11 and the θy angle range of the second rotating body 12 are simultaneously scanned with the center of intensity of the light 59 detected in step S2 set as the origin in a manner similar to the case of step S2. The CPU 71 stores the light intensity distribution at each angle in the RAM 73.

[0038]

In step S6, the CPU 71 detects the maximum value of the light intensity from the light intensity distribution stored in the RAM 73.

In step S7, the CPU 71 compares the maximum value of the light intensity detected in step S6 with the maximum value of the light intensity detected in step S3. When the maximum value in step S6 is smaller than the maximum value in step S3, the processing proceeds to step S8. Otherwise, when the maximum value in step S6 is not smaller than the maximum value in step S3, the processing returns to step S4. More specifically, if the maximum value of the light intensity is not reduced, a maximum value larger than the maximum value in step S3 must exist. In this event, the CPU 71 repeats the flow starting from step S4. On the other hand, when the maximum value of the light intensity is reduced, the mirror 14 is directly opposite to the collimation lens 34 and there is no maximum value that is larger than the maximum value in step S3. Therefore, the processing proceeds to step S8 and subsequent steps. In the first embodiment, the directly opposite position refers to a position where the light

intensity reaches the maximum.

[0039]

In step S8, the CPU 71 controls the Z-axis drive motor 44 to move the optical fiber positioning base 42 in the Z-axis direction by a predetermined distance. In this manner, the distance between the optical fiber 36 and the collimation lens 34 is changed by the predetermined distance.

[0040]

In step S9, the θx angle range of the first rotating body 11 and the θy angle range of the second rotating body 12 are simultaneously scanned with the center of intensity of the light 59 detected in step S5 set as the origin in a manner similar to the case of step S5. The CPU 71 stores the light intensity distribution at each angle in the RAM 73.

[0041]

In step S10, the CPU 71 finds the maximum value of the light intensity from the light intensity distribution, and stores this value as the maximum value at the aligned position in the RAM 73.

The foregoing processing results in the determination of the relative distance between the optical fiber 36 and the collimation lens 34 at which the light intensity reaches the maximum. The optical fiber 36 is fixed to the capillary 35 with an adhesive, which is not shown, at the determined position. In this manner, the aligning operation is completed for the alignment collimator 32.

[0042]

The ranges of the scanning speeds in the θx and θy directions are determined as follows. Preferably, the speed of the fast scanning is in a range of 100 to 1 kHz; and the speed of the slow scanning is in a range of 0.1 to 10 Hz, so that the ratio of the speeds of the fast scanning and the slow scanning is in a range of 10 to 10000. More preferably, the speed of the fast scanning is in a range of 200 to 600 Hz; and the speed of the slow scanning is in a range of 0.2

to 5 Hz, so that the ratio of the speeds of the fast scanning and the slow scanning is in a range of 40 to 3000. Most preferably, the speed of the fast scanning is in a range of 300 to 500 Hz; and the speed of the slow scanning is in a range of 0.5 to 2 Hz, so that the ratio of the speeds of the fast scanning and the slow scanning is in a range of 150 to 1000. The first rotating body 11 is a goniostage, and the second rotating body 12 is a galvanoscanner.

[0043]

According to the first embodiment, the following advantages are provided.

(1) The mirror 14 is rotated at a high speed in one direction while the mirror 14 is rotated at a low speed in the other direction. This results in a reduction in a time required for detecting the angle of the mirror at which the light intensity reaches the maximum, as compared with the conventional apparatus in which the mirror is rotated in one direction at a time.

[0044]

(2) The output of the angle of the mirror 14 is sent to the CPU 71 in synchronism with the output of the light intensity measuring device 75, and the CPU 71 automatically performs signal processing. Therefore, the angle at which the light intensity reaches the maximum is detected in a short time.

[Second Embodiment]

A fiber collimator aligning method and an aligner according to a second embodiment will be described with reference to Figs. 5 to 8. Since the structure of the second embodiment is partially the same as that of the first embodiment, the differences will mainly be discussed.

[0045]

The fiber collimator aligner of the second embodiment is shown in Figs. 5 to 7. As illustrated in the drawing, the fiber collimator aligner of the second embodiment has an

optical transmission part 20, which serves as light directing means.

The optical transmission part 20 includes a lens, which is a master collimator 22, in place of the mirror 14 in the first embodiment. A moving base 27 constitutes scanning means. The movable platform 27 linearly moves along the X-axis and Y-axis orthogonal to the optical axis of the master collimator 22. The master collimator 22 has a tube 23; a collimation lens 24 disposed within the tube 23; a capillary 25 disposed on the inner surface of the tube 23; and an optical fiber 26 inserted into the capillary 25.

[0046]

The movable platform 27 has a mechanism that scans in one direction at a high speed and scans in the other direction at a low speed as in the first embodiment. The position of the movable platform 27 is supplied to a position output circuit 82.

[0047]

A light directing device 50, i.e., a light source 51 is optically connected to an optical fiber 36.

Fig. 7 is a schematic diagram of a signal processing part 90 of the aligner 200. The signal processing part 90 of the second embodiment includes an X-axis control circuit 80; a Y-axis control circuit 81; and a position output circuit 82. The X-axis control circuit 80 controls an X-axis motor 27a disposed on the movable platform 27. The Y-axis control circuit 81 controls a Y-axis motor 27b disposed on the movable platform 27 in addition to the electrical configuration of the first embodiment. That is, the signal processing part 90 of the second embodiment further includes the X-axis control circuit 80; the Y-axis control circuit 81; and the position output circuit 82 in addition to the control means of the first embodiment.

[0048]

Light is irradiated from the light source 51 to the

collimation lens 34 through the optical fiber 36. The light is converted to parallel light 59 by the collimation lens 34.

The parallel light 59 is converged by the collimation lens 24, and impinges on a light intensity measuring device 75 through the optical fiber 26. The output of the light intensity measuring device 75 is supplied to the CPU 71 in synchronism with the output of an angle output circuit 79 and the position output circuit 82. The CPU 71 detects the angles and positions at which the light intensity reaches a maximum.

[0049]

Since the master collimator 22 is supported by the movable platform 27, the first rotating body, and the second rotating body, the master collimator 22 is automatically rotated in two directions (θx, θy) by the first rotating body 11 and the second rotating body 12, respectively, and also linearly slide in two directions (x, y) by the movable platform 27 automatically. In other words, the master collimator 22 can automatically be varied simultaneously in the angles and positions. The angles of the master collimator 22 are changed, one faster than the other. Therefore, the signal processing part 90 can detect a maximum value of the light intensity within a scanning angle range in a relatively short time as in the first embodiment. In addition, the positions of the master collimator 22 are also changed, one faster than the other. Therefore, the signal processing part 90 can detect the maximum value of the light intensity within the scanning position range in a relatively short time. Preferably, the ratio of the higher moving speed to the lower moving speed is one to several hundreds. The maximum value of the light intensity within the angle range (θx, θy) and the position range (x, y) is detected while alternately changing the angles and positions of the master collimator 22.

[0050]

Fig. 8 illustrates a flow chart of an aligning method according to the second embodiment.

Since the basic flow is the same as the process in Fig. 4 of the first embodiment, the differences will be described. In the second embodiment, the angles of the master collimator 22 is scanned in two directions (θx, θy) by the first rotating body 11 and the second rotating body 12, respectively, and the positions of the master collimator 22 is changed in two directions (x, y) by the movable platform 27. Therefore, steps S1, S2, S5 and S9 of the second embodiment are different from the process of the first embodiment.

[0051]

In step S1, the CPU 71 performs scanning in the position range in addition to the scanning in the angle range executed in the first embodiment such that the reflected light 59 is found even if the optical axis of the master collimator 22 slightly deviates from the collimation lens 34. In other words, the CPU 71 sets an angle range to be slightly large, and performs scanning in two directions (θx, θy). Next, the CPU 71 fixes the master collimation lens 22 at the angle (θx, θy) at which the light intensity reaches the maximum, and sets the x position range and the y position range of the movable platform 27 to be slightly large. Then, the CPU 71 performs scanning of the position in two directions (x, y). Further, the CPU 71 fixes the movable platform 27 at the position (x, y) at which the light intensity reaches the maximum, and performs angle scanning in two directions (θx, θy) to detect an angle (θx, θy) at which the light intensity reaches the maximum. Then, at this position, the CPU 71 performs position scanning in two directions (x, y). The CPU 71 repeats the foregoing operations until the light intensity reaches a predetermined value in order to detect the light 59.

[0052]

In step S2, the CPU 71 calculates the center of a light

intensity distribution of the detected light 59, and reduces the angle range. The CPU 71 performs angle scanning in two directions (θx, θy) with the calculated center set as the origin. Next, the CPU 71 reduces the x position range and the y position range of the movable platform 27 at an angle (θx, θy) at which the light intensity reaches the maximum, and performs position scanning in two directions (x, y). Subsequently, the CPU 71 performs angle scanning in two directions (θx, θy) at a position (x, y) at which the light intensity reaches the maximum. Again, the CPU 71 performs position scanning in two directions (x, y) at an angle (θx, θy) at which the light intensity reaches the maximum. The angle and position scanning is repeated until the maximum value of the light intensity hardly changes even if the angle and position of the master collimation lens 22 are changed. The CPU 71 stores the light intensity distribution defined by the angle and position in the RAM 73.

[0053]

In step S5, first, the CPU 71 performs angle scanning in two directions (θx, θy) with the center of the light 59 detected in step S2 set as the origin. Next, the CPU 71 performs position scanning in two directions (x, y) of the movable platform 27 at an angle (θx, θy) at which the light intensity reaches the maximum. Similarly to step S2, the angle and position scanning is repeated until the maximum value of the light intensity hardly changes even if the angle and position of the master collimation lens 22 are changed. The CPU 71 stores the light intensity distribution defined by the angle and position in the RAM 73.

[0054]

In step S9, first, the CPU 71 performs angle scanning in two directions (θx, θy) with the center of light 59 detected in step S5 set as the origin. Next, the CPU 71 performs position scanning in two directions (x, y) of the movable platform 27 at an angle (θx, θy) at which the light intensity

reaches the maximum. Similarly to step S2, the angle and position scanning is repeated until the maximum value of the light intensity hardly changes even if the angle and position of the master collimation lens 22 are changed. The CPU 71 stores the light intensity distribution defined by the angle and position in the RAM 73.

[0055]

The processing in Fig. 8 results in the determination of the relative distance between the optical fiber 36 and the collimation lens 34 at which the light intensity reaches the maximum. The optical fiber 36 is fixed to the capillary 35 with an adhesive, which is not shown, at the determined position. In this manner, the aligning operation is completed for the alignment collimator 32.

[0056]

The ranges of the scanning speeds in the θx and θy directions in the second embodiment are similar to those in the first embodiment. Preferably, the speed of the fast scanning is in a range of 100 to 1 kHz; and the speed of the slow scanning is in a range of 0.1 to 10 Hz, so that the ratio of the speeds of the fast scanning and the slow scanning is in a range of 10 to 10000. More preferably, the speed of the fast scanning is in a range of 200 to 600 Hz; and the speed of the slow scanning is in a range of 0.2 to 5 Hz, so that the ratio of the speeds of the fast scanning and the slow scanning is in a range of 150 to 1000. Most preferably, the speed of the fast scanning is in a range of 300 to 500 Hz; and the speed of the slow scanning is in a range of 0.5 to 2 Hz, so that the ratio of the speeds of the fast scanning and the slow scanning is in a range of 40 to 3000. On the other hand, as to the range of the scanning speed in the x and y directions, the speed of the fast scanning is in a range of 100 to 1 kH; and the speed of the slow scanning is in a range of 0.1 to 10 Hz, with the ratio of the two speeds ranging from 10 to 10000. More preferably,

the speed of the fast scanning is in a range of 200 to 600 Hz, and speed of the slow scanning is in a range of 0.2 to 5 Hz, with the ratio of the two speeds ranging from 150 to 1000. Most preferably, the speed of the fast scanning is in a range of 300 to 500 Hz, and the speed of the slow scanning is in a range of 0.5 to 2 Hz, with the ratio of the two speeds ranging from 40 to 3000.

[0057]

According to the second embodiment, the following advantages are provided.

(3) When the lens, which is the master collimator 22, is rotated and moved, one of the rotations is faster than the other. Further, one of the movements is faster than the other. Therefore, the detection of the angles and positions of the master collimator 22 at which the light intensity reaches the maximum can be made in a shorter time, as compared to an apparatus in which the master collimator 22 is rotated in one direction at a time and moved in one direction at a time.

[0058]

(4) The output of the light intensity measuring device 75 is supplied to the CPU 71 in synchronism with the output of the angle and position of the lens, which is the master collimator 22. The CPU 71 can detect in a shorter time the angle and position at which the light intensity reaches the maximum.

[Third Embodiment]

A method and an apparatus for testing a light intensity of a fiber collimator according to a third embodiment of the present invention will be described with reference to Figs. 9 to 12. Since the structure of the third embodiment is partially the same as that of the second embodiment, the differences will mainly be discussed.

[0059]

Figs. 9 to 11 illustrate an apparatus for testing a

fiber collimator. As shown in the drawing, the movable part 40 of the second embodiment is omitted in the testing apparatus of the third embodiment. Also, a testing part 60 is provided instead of the aligning part 30 of the second embodiment. That is, a testing work, which is a testing collimator 62, is provided instead of the alignment collimator 32. As shown in Fig. 10, the structure of the testing collimator 62 is the same as the aligning collimator 32.

[0060]

Fig. 11 is a schematic diagram of a signal processing part 91 of the apparatus of the third embodiment. The signal processing part 91 omits the Z-axis drive signal processing circuit 76 in Fig. 7.

As in the second embodiment, the maximum value of the light intensity within the angle range (θx, θy) and the position range (x, y) is detected while alternately changing the angles and positions of the master collimator 22.

[0061]

Fig. 12 is a flow chart of a testing method according to the third embodiment. Since the basic flow is the same as the process in Fig. 8 of the second embodiment, the differences will be described. In the third embodiment, after performing operations that are the same as steps S1 and S2 in Fig. 8, step S3 is performed as follows.

[0062]

In step S3, the CPU 71 reads the maximum value of the light intensity from the light intensity distribution stored in the RAM 73, and writes the maximum value into the RAM 73.

In this manner, by the operation shown in Fig. 12, the collimator 62 under testing is tested based on the maximum value of the light intensity.

[0063]

The ranges of the scanning speeds in the θx and θy directions in the third embodiment are similar to those in

the above embodiments. Preferably, the speed of the fast scanning is in a range of 100 to 1 kHz; and the speed of the slow scanning is in a range of 0.1 to 10 Hz, so that the ratio of the speeds of the fast scanning and the slow scanning is in a range of 10 to 10000. More preferably, the speed of the fast scanning is in a range of 200 to 600 Hz; and the speed of the slow scanning is in a range of 0.2 to 5 Hz, so that the ratio of the speeds of the fast scanning and the slow scanning is in a range of 150 to 1000. Most preferably, the speed of the fast scanning is in a range of 300 to 500 Hz; and the speed of the slow scanning is in a range of 0.5 to 2 Hz, so that the ratio of the speeds of the fast scanning and the slow scanning is in a range of 40 to 3000. On the other hand, as to the range of the scanning speed in the x and y directions, the speed of the fast scanning is in a range of 100 to 1 kH; and the speed of the slow scanning is in a range of 0.1 to 10 Hz, with the ratio of the two speeds ranging from 10 to 10000. More preferably, the speed of the fast scanning is in a range of 200 to 600 Hz, and speed of the slow scanning is in a range of 0.2 to 5 Hz, with the ratio of the two speeds ranging from 150 to 1000. Most preferably, the speed of the fast scanning is in a range of 300 to 500 Hz, and the speed of the slow scanning is in a range of 0.5 to 2 Hz, with the ratio of the two speeds ranging from 40 to 3000.

[0064]

According to the third embodiment, the following advantages are provided.

(5) The apparatus of the third embodiment can detect in a relatively short time the maximum value of the light intensity within the predetermined angle range and the position range. Therefore, using the output value of the detected maximum light intensity, the testing collimator is tested in a relatively short time.

[0065]

(Modified Examples)

The first through third embodiments may be modified in the following manner.

· In the first embodiment, the mirror 14, which serve as the light directing means, is scanned by the first rotating body 11 and the second rotating body 12. However, the first rotating body 11 and the second rotating body 12 may be located in a position towards the alignment work, and the alignment collimator 32 may be scanned by the first rotating body 11 and the second rotating body 12. In this case, since the first rotating body 11 and the second rotating body 12 are provided to change the relative angle between the alignment collimator 32 and the mirror 14, the advantages of the first embodiment can be still provided even in a case where the alignment collimator 32 is scanned.

[0066]

· In the second embodiment, the master collimator 22 is scanned by the first rotating body 11, the second rotating body 12, and the movable platform 27. However, the first rotating body 11, the second rotating body 12, and the movable platform 27 may be located in a position towards the alignment collimator 32, and may scan the alignment collimator 32.In this case, since the first rotating body 11, the second rotating body 12, and the movable platform 27 are provided to change the relative angle and the position between the master collimator 22 and the alignment collimator 32, the advantages of the second embodiment can be still provided even in a case where the alignment collimator 32 is rotated and moved.

[0067]

· In the second embodiment, the master collimator 22 is scanned by the first rotating body 11, the second rotating body 12, and the movable platform 27. However, the alignment collimator 32 may be rotated by the first rotating body 11 and the second rotating body 12, while the master collimator

22 may be moved by the movable platform 27. Alternatively, the alignment collimator 32 may be moved by the movable platform 27, while the master collimator 22 may be rotated by the first rotating body 11 and the second rotating body 12. In this case, since the first rotating body 11, the second rotating body 12, and the movable platform 27 are provided to change the relative angle and the position between the alignment collimator 32 and the master collimator 22, the advantages of the second embodiment can be still provided even in a case where one of the alignment collimator 32 and the master collimator 22 is rotated and the other is moved.

[0068]

· In the second embodiment, light of the light source 51 is irradiated from the alignment collimator 32, and the light intensity measuring device 75 is located behind the master collimator 22. However, light from the light source 51 may be irradiated from the master collimator 22, and the light intensity measuring device 75 may be located behind the alignment collimator 32. In this configuration, the light from the light source 51 is irradiated from the master collimator 22 through the optical fiber 26. The light is sent out from the optical fiber 36 through the alignment collimator 32. In this case, the advantages of the second embodiment can be still provided even in a case where the light source 51 is connected to the optical fiber 26 of the master collimator 22 and the light intensity measuring device 75 is connected to the optical fiber 36 of the alignment collimator 32.

[0069]

· In the third embodiment, the master collimator 22 is scanned by the first rotating body 11, the second rotating body 12, and the movable platform 27. However, the testing collimator 62 may be scanned by the first rotating body 11, the second rotating body 11, and the movable platform 27. In this case, since the first rotating body 11, the second

rotating body 12, and the movable platform 27 are provided for changing the relative angle and the position between the master collimator 22 and the testing collimator 62, the advantages of the third embodiment can be still provided even in a case where the testing collimator 62 is rotated and moved.

[0070]

· In the third embodiment, the master collimator 22 is scanned by the first rotating body 11, the second rotating body 12, and the movable platform 27. However, the first rotating body 11 and the second rotating body 12 may rotate the testing collimator 62, while the movable platform 27 may move the master collimator 22. Alternatively, the testing collimator 62 may be moved by the movable platform 27, while the master collimator 22 may be rotated by the first rotating body 11 and the second rotating body 12. In this case, since the first rotating body 11, the second rotating body 12, and the movable platform 27 are provided for changing the relative angle and the position between the testing collimator 62 and the master collimator 22, the advantages of the third embodiment can be still provided even in a case where one of the testing collimator 62 and the master collimator 22 is rotated and the other is moved.

[0071]

· In the third embodiment, the light of the light source 51 is irradiated from the testing collimator 62, and the light intensity measuring device 75 is located behind the master collimator 22. However, the light of the light source 51 may be irradiated from the master collimator 22, and the light intensity measuring device 75 may be located behind the testing collimator 62. In this case, the light from the light source 51 is irradiated from the master collimator 22 through the optical fiber 26. The light is sent out from the optical fiber 36 through the testing collimator 62. In this case, the advantages of the third embodiment can be still

provided even in a case where the light source 51 is connected to the optical fiber 26 of the master collimator 22 and the light intensity measuring device 75 is connected to the optical fiber 36 of the testing collimator 62.

[0072]

· In the third embodiment, the movable part 40 and the z-axis drive signal processing circuit 76 of the second embodiment are omitted. However, the movable part 40 and the z-axis drive signal processing circuit 76 need not be omitted, and the structure that is the same as the second embodiment may be used. In other words, the same apparatus may be used in the second and third embodiments. In this case, the same apparatus can be used for either of the testing and alignment for a fiber collimator.

[0073]

[Effects of the Invention]

As described above, according to the present invention, an angle at which the light intensity reaches the maximum is detected in a short time. Therefore, the invention is superior as a method and an apparatus for aligning a fiber collimator and as a light intensity testing method and an apparatus for testing a fiber collimator.

[Brief Description of the Drawings]

[Fig. 1] A perspective view of an aligner according to a first embodiment.

[Fig. 2] A schematic diagram of the aligner according to a first embodiment.

[Fig. 3] A block diagram showing an electric configuration of the aligner according to the first embodiment.

[Fig. 4] A flow chart of an aligning method according to the first embodiment.

[Fig. 5] A perspective view of an aligner according to a second embodiment.

[Fig. 6] A schematic diagram of the aligner according to the second embodiment.

[Fig. 7] A block diagram showing an electric configuration of the aligner according to the second embodiment.

[Fig. 8] A flow chart of an aligning method according to the second embodiment.

[Fig. 9] A perspective view of an aligner according to a third embodiment.

[Fig. 10] A schematic diagram of the aligner according to the third embodiment.

[Fig. 11] A block diagram showing an electric configuration of the aligner according to the third embodiment.

[Fig. 12] A flow chart of an aligning method according to the third embodiment.

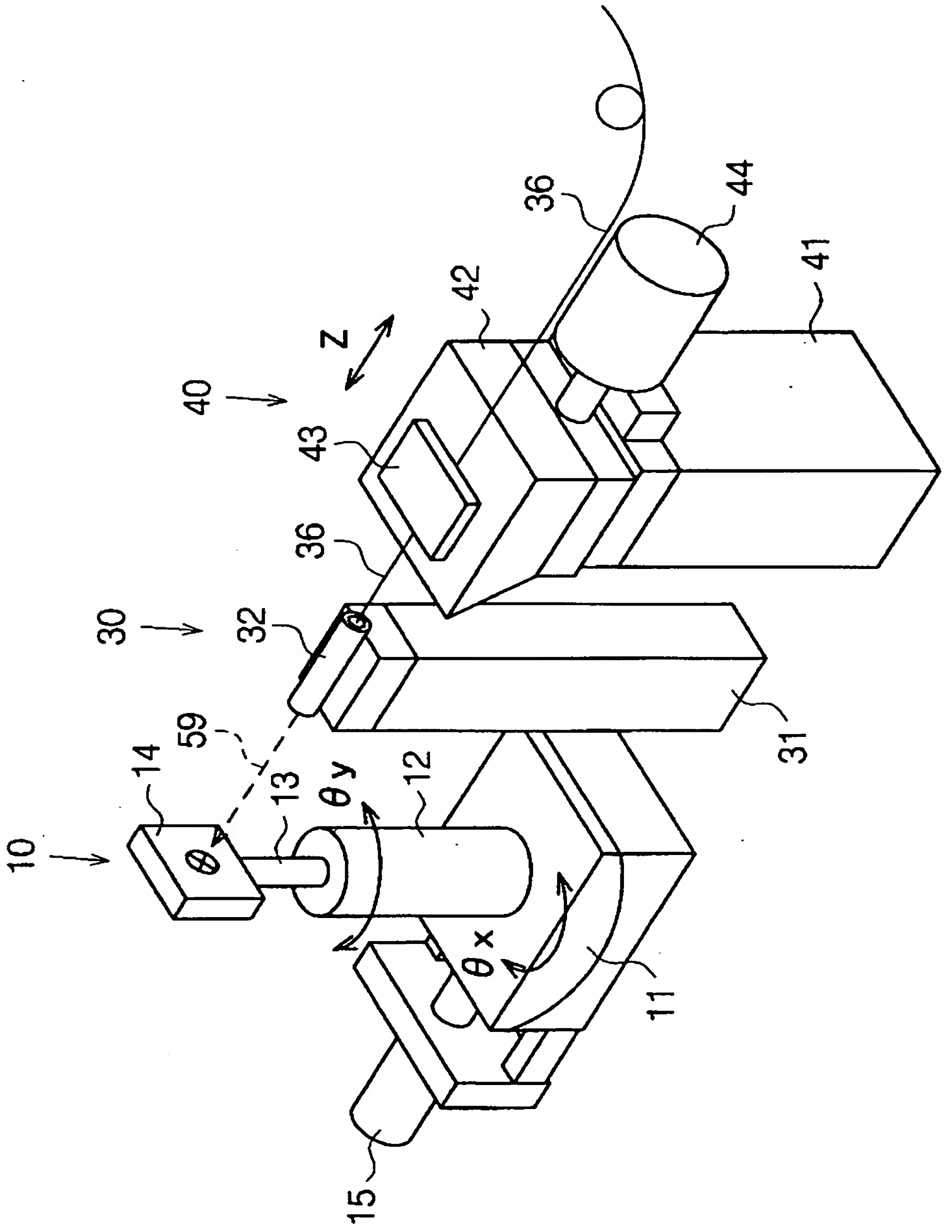
[Fig. 13] A perspective view of a conventional fiber collimator aligner.

[Description of the Reference Numerals]

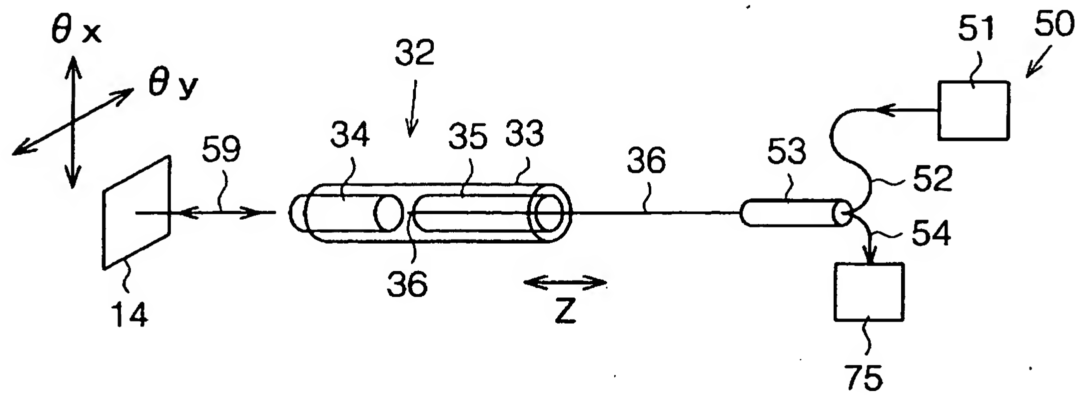
10···reflector, 11, 12···rotating body, 14···mirror, 20···optical transmission part, 22···master collimator, 24, 34···collimation lens, 26, 36···optical fiber, 30···aligning part, 31···work holder, 32···alignment collimator, 40···movable part, 50···light directing unit, 51···light source, 53···optical splitter, 60···testing part, 62···testing collimator, 70, 90, 91···signal processing part, 75···light intensity measuring device, 79···angle output circuit, 82···position output circuit.

[Title of Document] Drawings

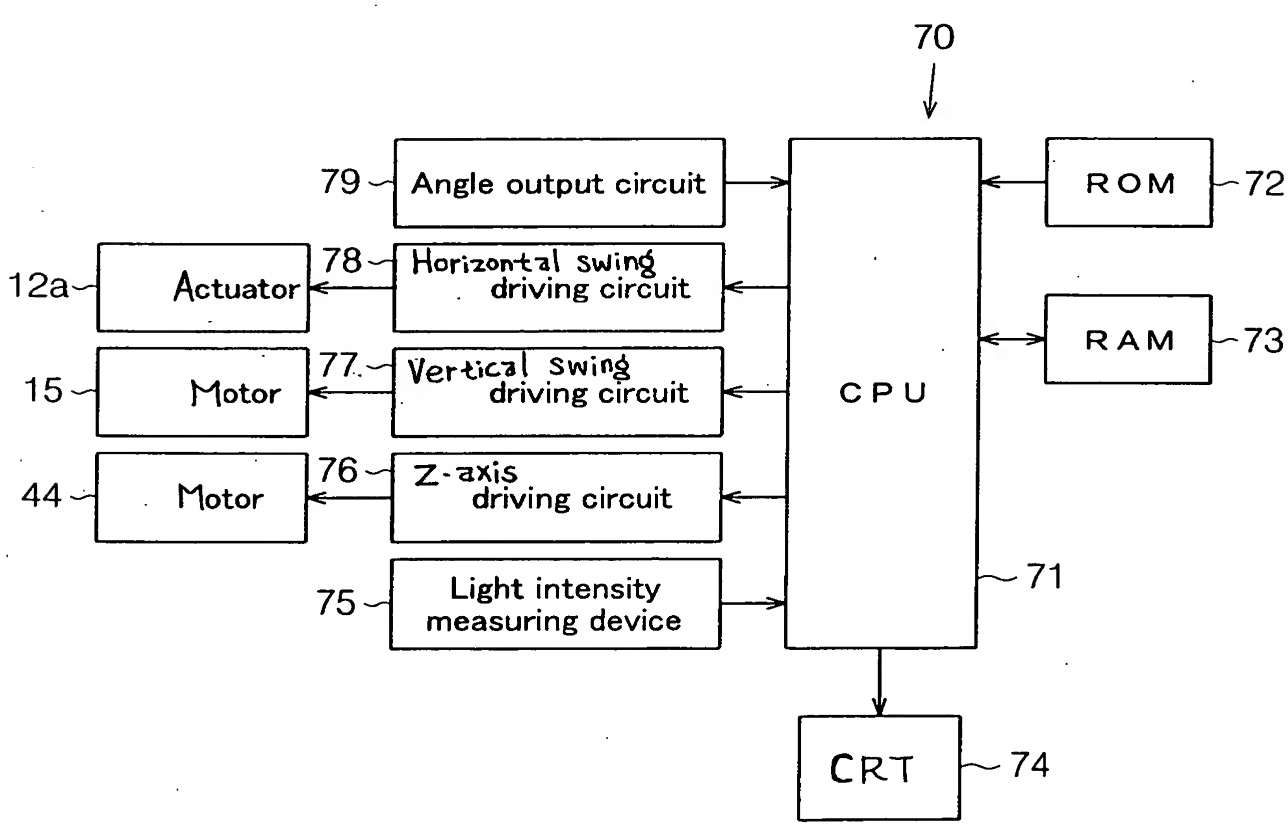
[Fig.1]



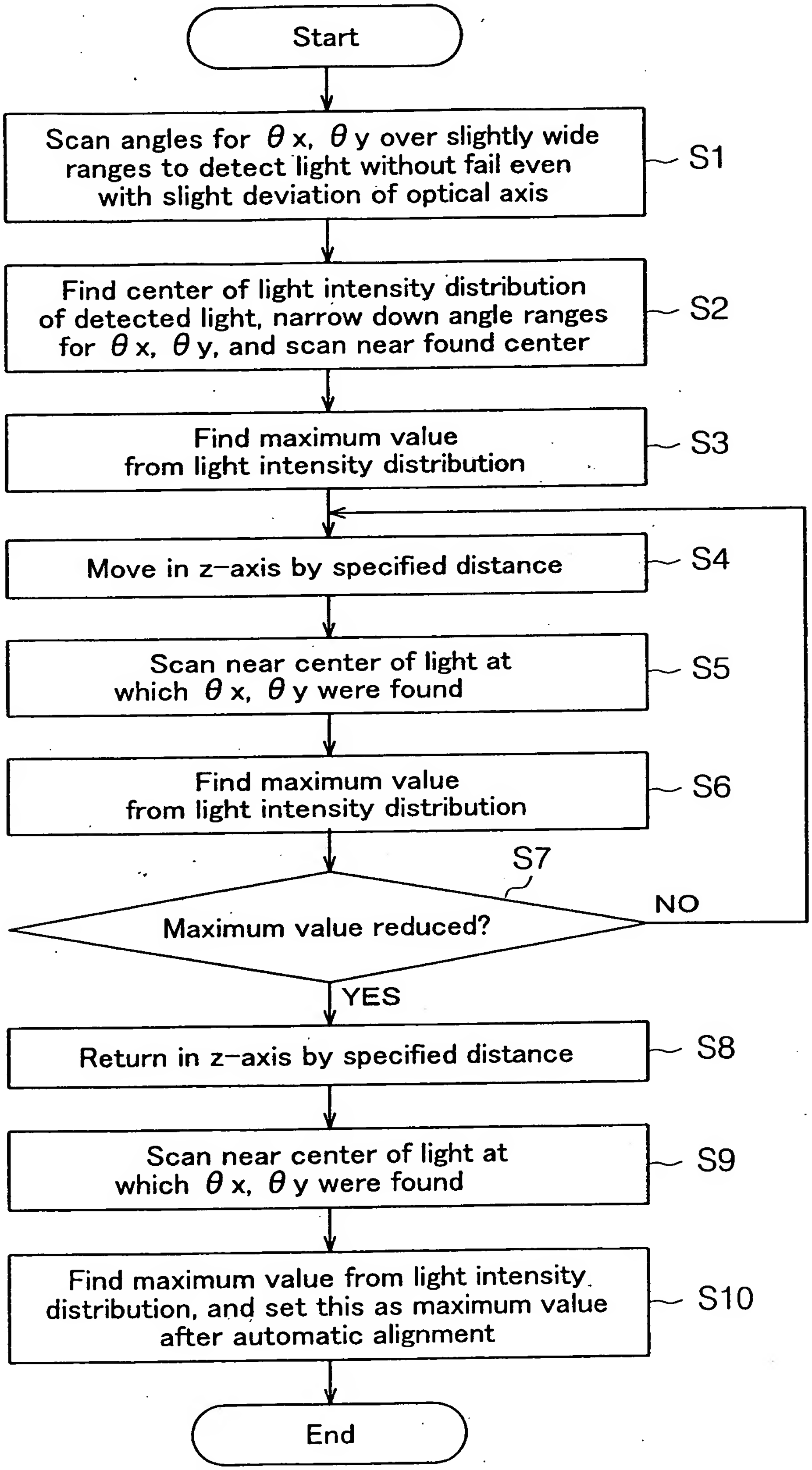
[Fig. 2]


θx
θy
59
34
32
35
33
36
53
51
50
52
54
14
36
Z
75

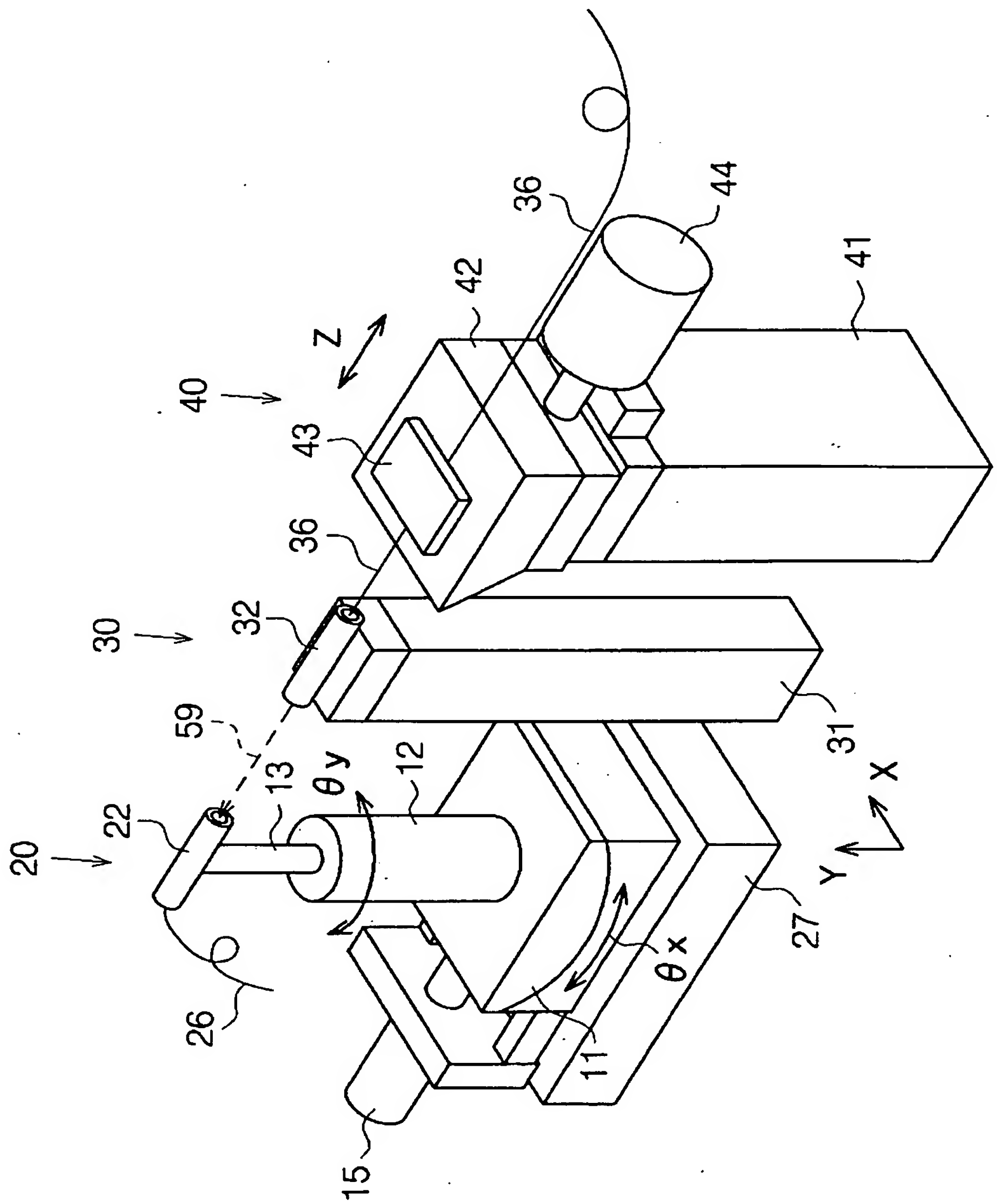
[Fig.3]


70
79
Angle output circuit
ROM
72
12a
Actuator
78
Horizontal swing driving circuit
RAM
73
15
Motor
77
Vertical swing driving circuit
CPU
44
Motor
76
Z-axis driving circuit
75
Light intensity measuring device
71
CRT
74

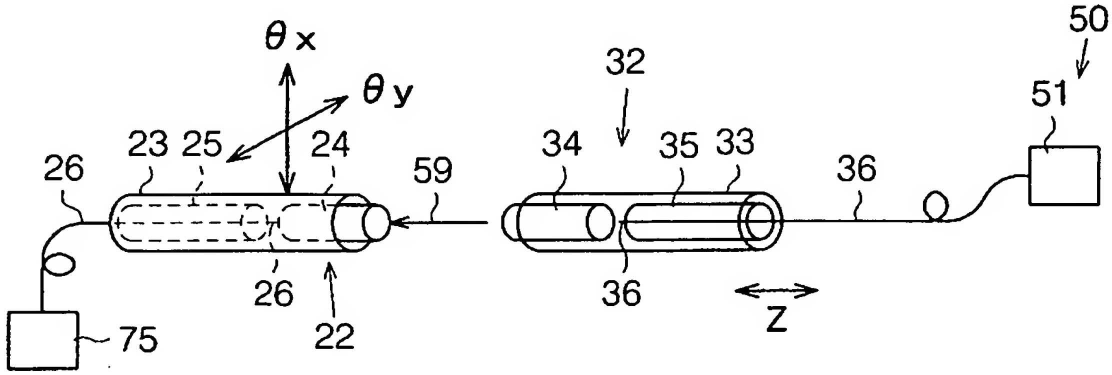
[Fig.4]


Start
Scan angles for θx, θy over slightly wide ranges to detect light without fail even with slight deviation of optical axis
S1
Find center of light intensity distribution of detected light, narrow down angle ranges for θx, θy, and scan near found center
S2
Find maximum value from light intensity distribution
S3
Move in z-axis by specified distance
S4
Scan near center of light at which θx, θy were found
S5
Find maximum value from light intensity distribution
S6
S7
Maximum value reduced?
NO
YES
Return in z-axis by specified distance
S8
Scan near center of light at which θx, θy were found
S9
Find maximum value from light intensity distribution, and set this as maximum value after automatic alignment
S10
End

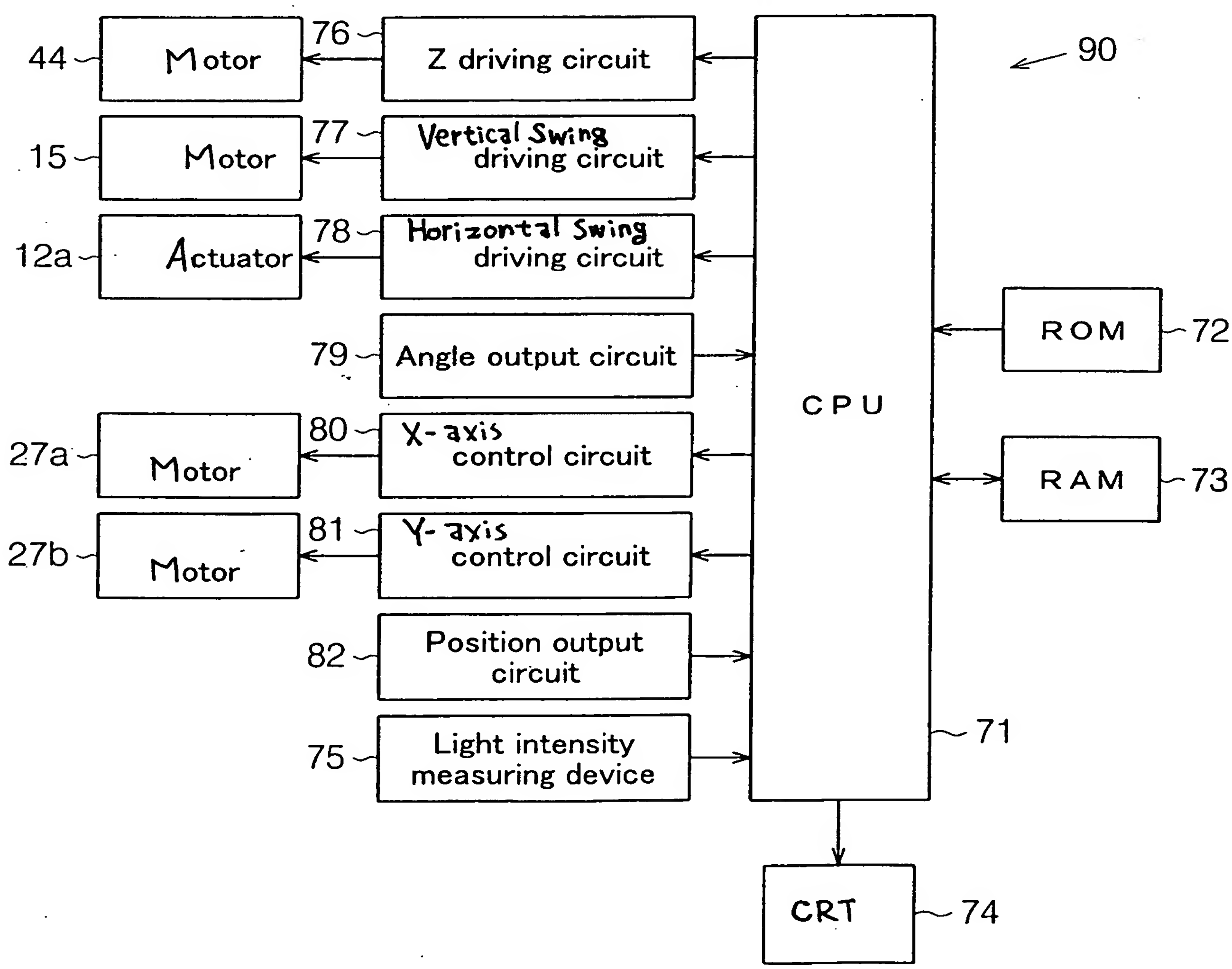
[Fig.5]



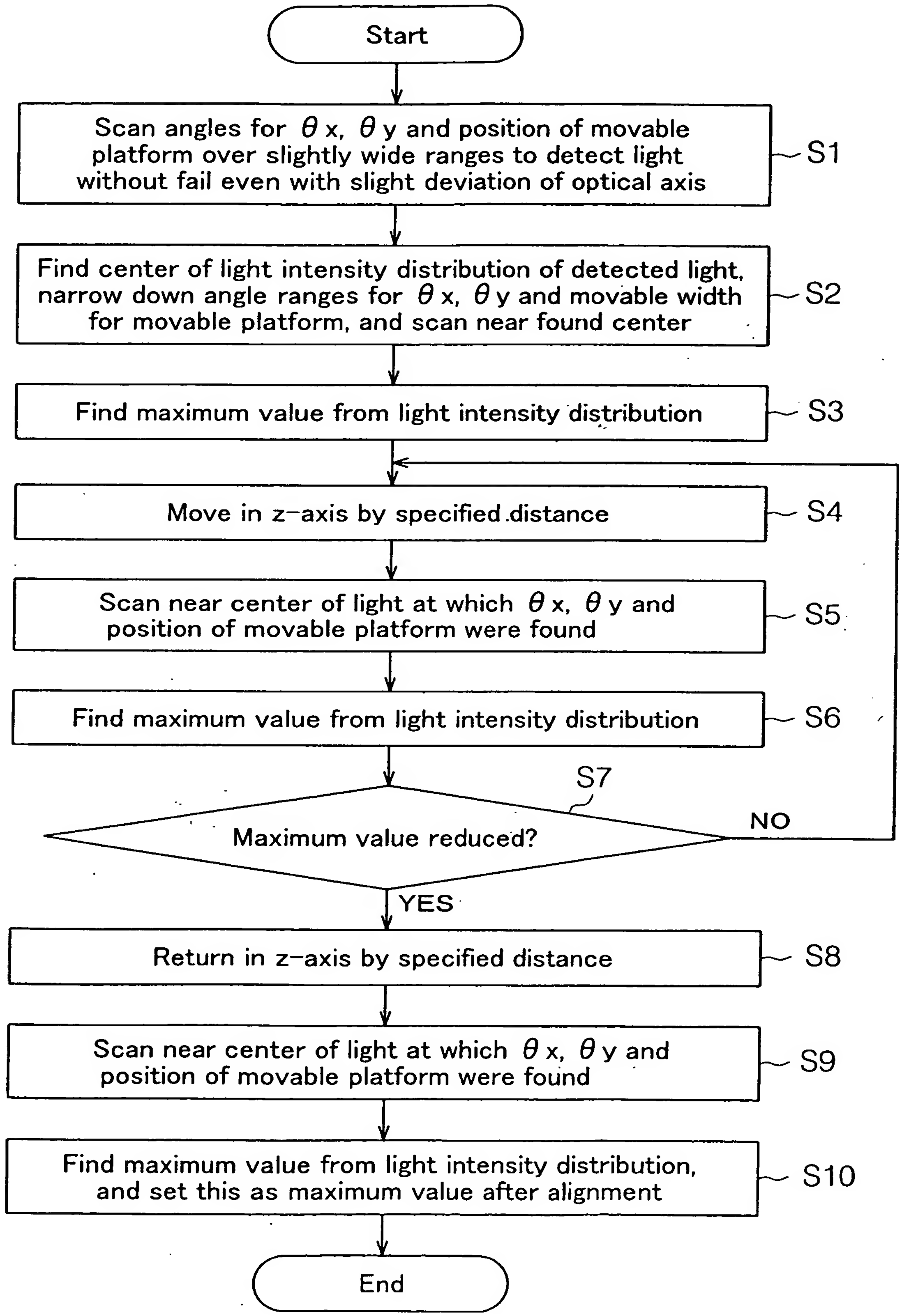
[Fig.6]


θx
θy
50
51
32
34
35
33
36
23 25
24
26
59
36
26
22
75
Z

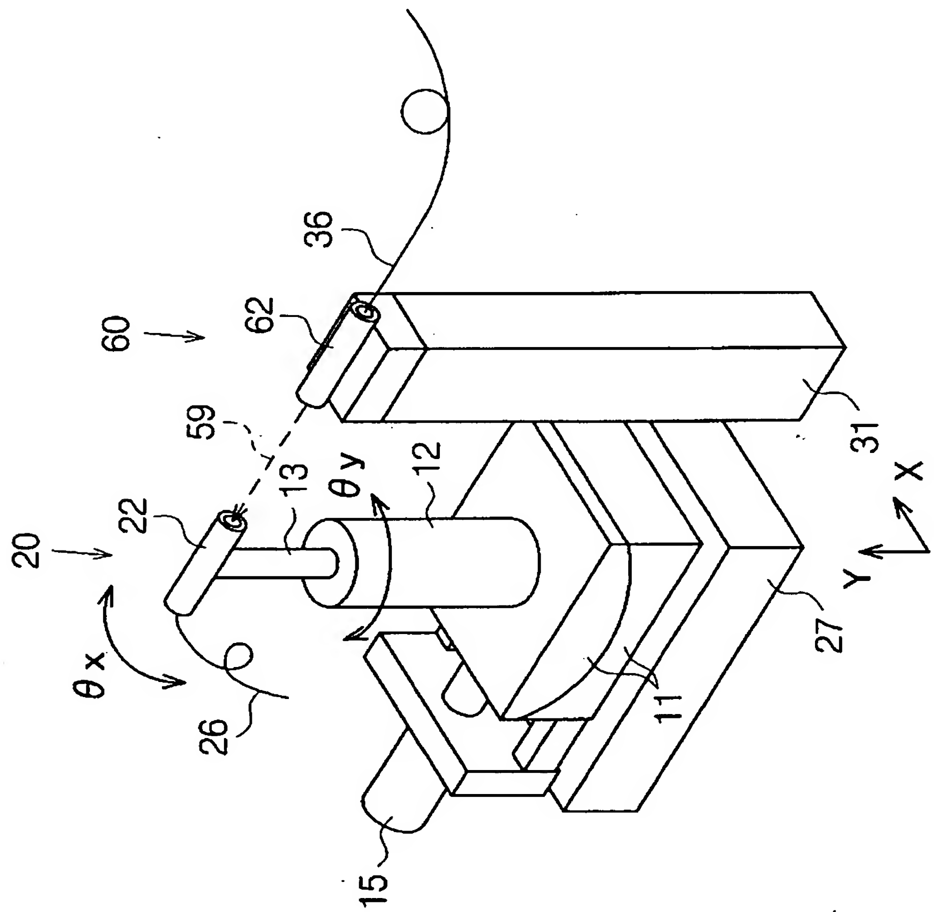
[Fig.7]


44
Motor
76
Z driving circuit
15
Motor
77
Vertical Swing driving circuit
12a
Actuator
78
Horizontal Swing driving circuit
79
Angle output circuit
27a
Motor
80
X-axis control circuit
27b
Motor
81
Y-axis control circuit
82
Position output circuit
75
Light intensity measuring device
CPU
90
ROM
72
RAM
73
71
CRT
74

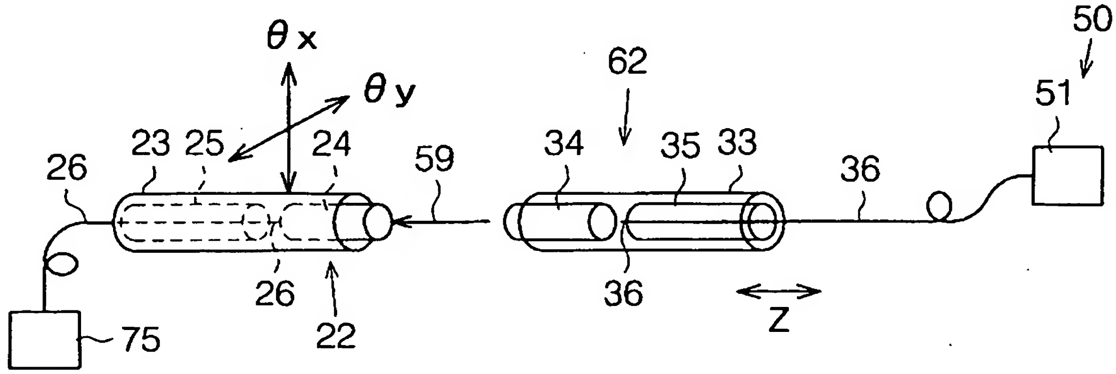
[Fig.8]


Start
Scan angles for θx, θy and position of movable platform over slightly wide ranges to detect light without fail even with slight deviation of optical axis
S1
Find center of light intensity distribution of detected light, narrow down angle ranges for θx, θy and movable width for movable platform, and scan near found center
S2
Find maximum value from light intensity distribution
S3
Move in z-axis by specified distance
S4
Scan near center of light at which θx, θy and position of movable platform were found
S5
Find maximum value from light intensity distribution
S6
S7
Maximum value reduced?
NO
YES
Return in z-axis by specified distance
S8
Scan near center of light at which θx, θy and position of movable platform were found
S9
Find maximum value from light intensity distribution, and set this as maximum value after alignment
S10
End

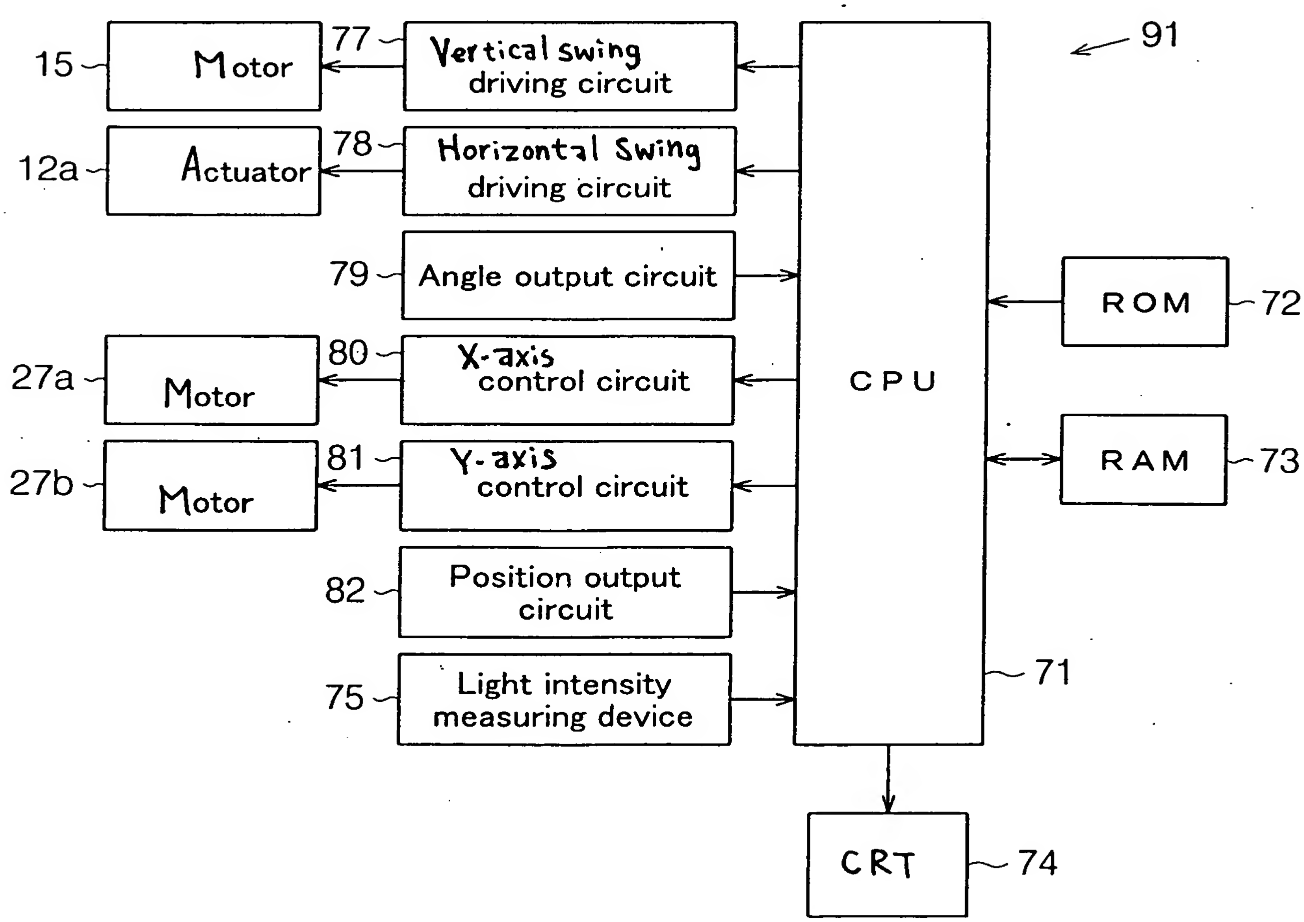
[Fig.9]



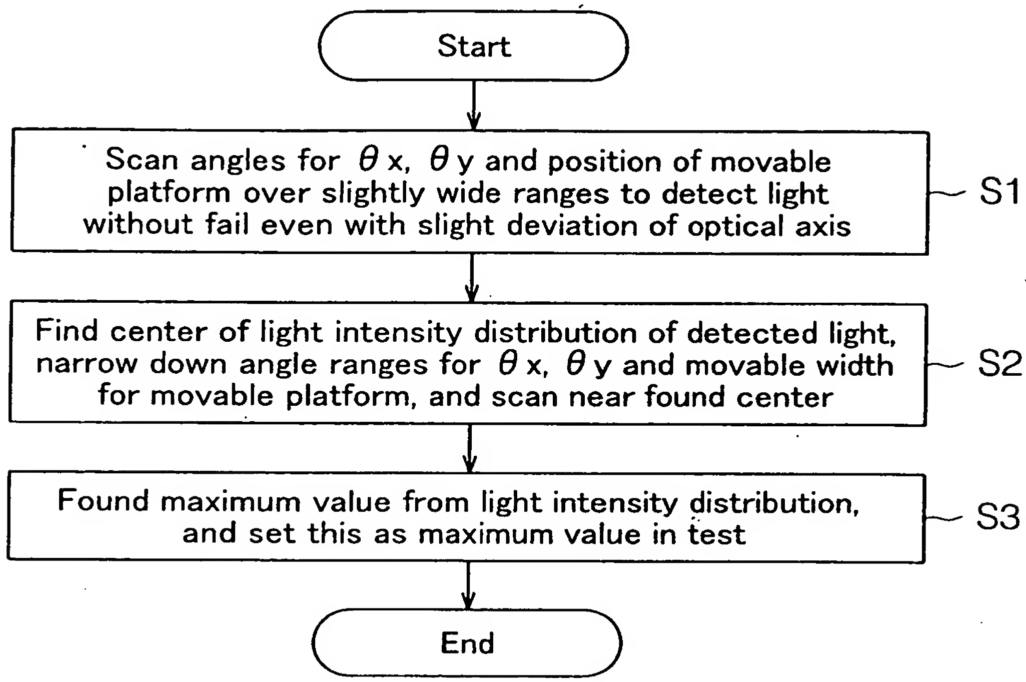
[Fig.10]


θx
θy
62
50
51
23 25
24
59
34
35 33
36
26
26
36
22
75
Z

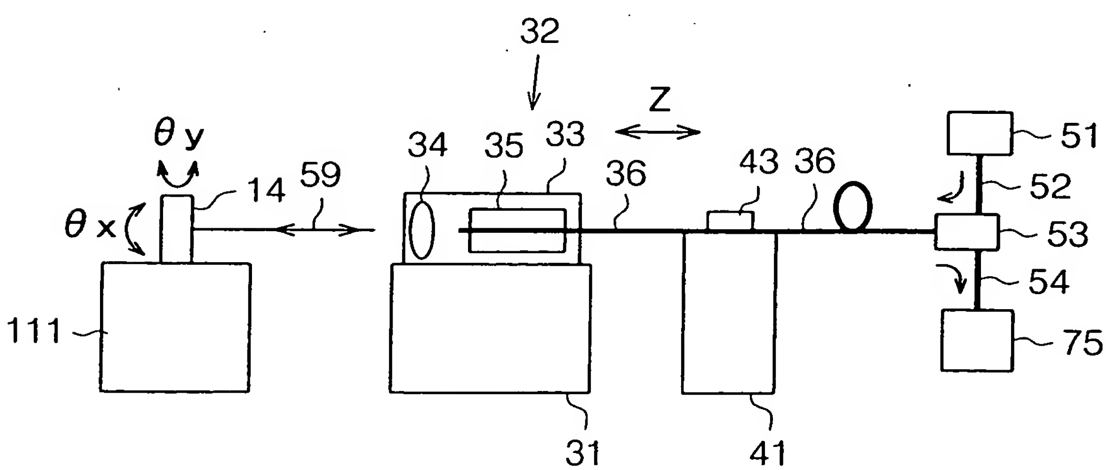
[Fig.11]


15
Motor
77
Vertical swing driving circuit
91
12a
Actuator
78
Horizontal Swing driving circuit
79
Angle output circuit
ROM
72
27a
Motor
80
X-axis control circuit
CPU
27b
Motor
81
Y-axis control circuit
RAM
73
82
Position output circuit
75
Light intensity measuring device
71
CRT
74

[Fig.12]


Start
Scan angles for θx, θy and position of movable platform over slightly wide ranges to detect light without fail even with slight deviation of optical axis
S1
Find center of light intensity distribution of detected light, narrow down angle ranges for θx, θy and movable width for movable platform, and scan near found center
S2
Found maximum value from light intensity distribution, and set this as maximum value in test
S3
End

[Fig.13]


32
Z
θy
θx
14
59
34
35
33
36
43
36
51
52
53
54
75
111
31
41

[Abstract]
[Objective] It is an objective of the present invention to provide a light intensity testing method and an apparatus which reduce a time required for detecting an optimized position at which a light intensity reaches the maximum, and an aligning method and an apparatus for a fiber collimator.
[Means for Solving the Problems] A mirror 14 is located in a position towards the outgoing end of the alignment collimator 32. A light intensity measuring device 75 detects the light that has been reflected by the mirror 14 and passed through the alignment collimator 32, while aligning the alignment collimator 32 at a Z-axis position where the light intensity reaches the maximum. The mirror 14 is attached to rotating bodies 11, 12 that scan in two directions with respect to an optical axis. Since the rotating bodies 11, 12 scan in one of the directions faster than the other, the optimized position of the mirror 14 is detected in a short time as compared to a an apparatus in which the mirror is rotated in one direction at a time. This results in reduction of the time required for aligning the alignment collimator 32.
[Selected Drawing] Fig. 1